From: O'Carroll, E. & McClure, M. (eds), *South-West Donegal.* Field Guide No. 34, Irish Quaternary Association, Dublin, 51-58.
(ISBN 978 0 947 920 57 9)

7. Rock-slope failures in southwest Donegal

Peter Wilson

Introduction

The term rock-slope failure (RSF) is applied by geomorphologists to both a process and a landform. In terms of process, RSF is a mass-movement in which a large body of bedrock travels some distance downslope under gravity from its place of origin. The distance of travel may be just a few metres or many kilometres, and the rock body can remain largely coherent or can disintegrate into boulders and smaller calibre debris. Generally, the greater the distance of travel the greater is the likelihood of disintegration, although this is also dependent on rate of descent, underlying slope gradient, and the characteristics of the rock (particularly its structural properties). Sometimes an external factor such as an earthquake, volcanic eruption, sudden increase in water pressure, or significant fluctuation in temperature may trigger RSF. In other cases, long-term weathering may weaken the rock such that it fails without the need for an external trigger. In many areas RSF is an important process in the narrowing and lowering of mountain masses.

As landforms, RSFs are usually classified on the basis of their morphology. In the Highlands of Scotland Jarman (2006) has recognised five modes of failure. This categorisation is also applicable in the English Lake District (Wilson & Jarman, 2015) and can be applied to RSFs in Ireland given the similarities with the UK in terms of rock formations and structure, and landscape history (i.e. former glaciation). These types of RSF are outlined in Figure 7.1.

Rock avalanches: these RSFs are sub-divided into cataclasmic and sub-cataclasmic. They are failures that have substantially evacuated their source areas and the failed materials extend to the slope foot or beyond. The leading edge of the debris in sub-cataclasmic failures may have reached the slope foot with other debris piled up behind it.

Arrested rockslides: these are RSFs that have travelled a relatively short distance downslope from their source areas before 'stabilising', and in which the failed materials remain as semi-intact or coherent masses. As travel distance increases, slides are likely to undergo increasing amounts of disintegration and transform into a type of rock avalanche.

Rock slope deformations: both extensional and compressional modes of failure are included here. Those of the former category normally have distinct headscarps, and holes, fissures and grabens in their upper reaches, with an overall forward-tilting morphology and areas of gravitational sagging. Compressional deformations often lack a headscarp and are dominated by upthrust ridges of 'reverse-fault' character that often divide slopes in a lattice manner. These failures may appear to be substantially coherent, and difficult to distinguish from adjacent slopes. Some slope deformations may exhibit elements of extension in their upper reaches and compression in their lower zones.

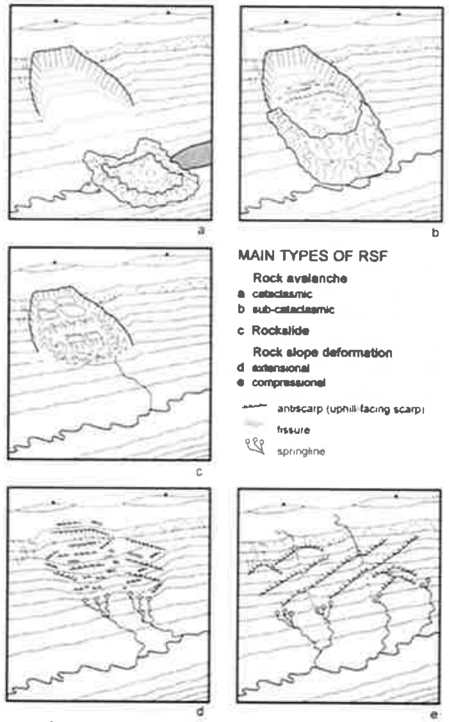

Fig. 7.1. The five types of rock-slope failure recognised in the Highlands of Scotland and English Lake District (after Jarman (2006) and Wilson & Jarman (2015)).

Rock-slope failures in Ireland

Although rock-slope failures have been recorded in several mountain areas, there is as yet no overview of their spatial distribution, morphology, and age. A brief discussion is provided by Wilson (2017). Several large RSFs characterise escarpments in Carboniferous strata in the Dartry Mountains and Fermanagh. The basalt scarps of the Antrim Lava Group have similarly undergone large-scale failure, as have the quartzite mountains of north Donegal (Wilson, 2004). RSFs in these latter areas have been subjected to terrestrial cosmogenic nuclide surface exposure dating (Ballantyne *et al.*, 2013; Southall *et al.*, 2017). Both studies indicate that the failures occurred shortly after Late Midlandian deglaciation ~18-17 ka.

In areas of former glaciation, RSFs are usually regarded as being of paraglacial origin. Paraglacial processes are defined as nonglacial processes that are directly conditioned by glaciation. The influence of ice masses on mountain slopes (in addition to erosion) is to cause compression (loading) during glacier expansion and to allow rebound (unloading) during glacier wastage. This can reduce rock-mass stability and RSF may occur as a consequence of stress-release. Crustal unloading may also promote seismic activity, which can in turn cause weakened mountain slopes to fail.

RSFs have also occurred on steep and high coastal cliffs. In these cases, wave action at cliff base may have been an influence, but given that Ireland was completely covered by ice during the Late Midlandian glaciation, a paraglacial origin for these failures cannot be easily dismissed One of the most impressive coastal RSFs seen by this author is on Croaghaun, Achill Island. On the cliff-top at 580 m above sea level (asl) and ~0.75 km northeast of the summit, a narrow chasm has opened. This is indicated by a contour re-entrant on Ordnance Survey 1:50,000 sheet 30 at grid reference 565 067. The outer part of the cliff has moved seawards but has not collapsed. It would seem likely that this semi-detached feature will one day descend to the waves, with a consequent narrowing of the Croaghaun ridge. The morphological evidence for RSF along this ridge represents the most recent phase of rock detachment – a process that has probably been ongoing since deglaciation.

Rock-slope failures in southwest Donegal

Several RSFs have been noted in the Slieve League – Glencolmcille area but they have not been mapped in detail and, with one exception, their age is unknown. These sites are on Ordnance Survey 1:50,000 sheet 10.

On the northeast flank of Slieve League at grid reference 558 775 a RSF consisting of a lobe of coarse rock debris extends downslope from the ridge crest at ~500 m asl to ~360 m asl; the Pilgrim's Path to the summit of Slieve League passes the toe of the debris (Fig. 7.2). The failure has lowered the ridge crest by 30 m, has narrowed it to an arête just a few metres in width, and has created a shallow cavity (debris source area) on the upper slope (Fig. 7.3). Three quartzite boulders from the toe of the debris lobe returned consistent cosmogenic nuclide (^{10}Be) surface exposure ages that average ~17 ka (Ballantyne *et al.*, 2013). There is no evidence that runout of debris was onto glacier ice and the inference is that the failure occurred after the local ice had wasted away. The failure most likely began as a translational slide but was partly transformed into a sub-cataclasmic rock avalanche.

Fig. 7.2. Large-scale boulder-covered lobe of a slide / sub-cataclasmic rock avalanche on Slieve League. The Pilgrim's Path can be seen close to the toe of the debris.

Fig. 7.3. Looking up the debris lobe of the Slieve League slide / rock avalanche shown in Figure 1. The failure extends downslope from the ridge crest, which has been lowered as a consequence. Three boulders from near the toe of the lobe have given cosmogenic nuclide (^{10}Be) surface exposure ages of ~17 ka.

Another area of failure on Slieve League is crossed when taking the footpath that leaves the cliff-top car park at Bunglass and heads towards the summit. Within a few hundred metres, around grid reference 564 760, the path passes through an area of fractured crags, low ridges and depressions, holes and fissures. The full extent of this

area of failure is not known, but as with the example from Achill Island given above, it is probably the most recent phase of a process that has been on-going since local deglaciation. By continuing along the cliff-top path the crest of the previously described Slieve League slide / sub-cataclasmic rock avalanche will be reached. Slieve League may have other areas of RSF that have not yet been recorded.

At least three areas of RSF have been seen in the vicinity of Glencolmcille. One of these is east of Skelpoonagh Bay, on the western flank of Craigbeefan (grid reference 524 863). The debris is disposed as a series of large mounds with many surface boulders (Fig. 7.4). Some debris mounds sit directly below the col connecting Beefan Mountain and the unnamed summit to the west with a Signal Tower. Failure morphology suggests an arrested slide / sub-cataclasmic rock avalanche.

Fig. 7.4. The debris mounds of a sub-cataclasmic rock avalanche below Craigbeefan, to the east of Skelpoonagh Bay, Glencolmcille.

On the hillside extending east from Craigbeefan and below the unnamed summit at 283 m asl, is an area of RSF occupying ~1 km^2 of ground (grid reference 540 856; Fig. 7.5). The upper reaches of the failure, above the highest houses visible in Fig. 7.5, are used for rough grazing. The mid- and lower reaches have been improved and enclosed. There are few surface boulders on the debris, although any that previously existed could have been cleared for wall construction. The failed materials take the form of mega-blocks, some with flat or gently sloping upper surfaces and steeper frontal slopes. These steep fronts may indicate that the mega-blocks came to rest against the flank of a decaying valley glacier that buttressed them or that they moved slowly into position after the glacier had decayed. Either way the mega-blocks retained their integrity rather than disintegrating to boulder-sized debris.

Fig. 7.5. Large-scale arrested rockslide on the hillside to the northwest of Glencolmcille. Failed masses of bedrock extend from near the hillcrest to the valley floor. Steepening of the lower slopes may be because the failed masses came to rest against the flank of the last decaying valley glacier.

The third area of RSF lies on the cliff-top north of Skelpoonagh Bay in the vicinity of the Signal Tower (my notes from several years ago do not include a grid reference!). A failed mass of rock is evidenced by the shallow linear trench running parallel to the cliff-top (Fig. 7.6). The trench is bounded by a rock parapet on its seaward side and by a bedrock scarp on its landward side that is, in part, covered by vegetation and boulders. As with the cliff-top failures mentioned above, this feature is testimony to an earlier episode of large-scale rock-slope instability.

Fig. 7.6. This linear depression on the cliff-top north of Skelpoonagh Bay indicates outward and downward movement of the cliff; it represents the top of an arrested slide mass.

Together these five areas of RSF comprise a very small proportion of the Slieve League – Glencolmcille peninsula (<2 km^2). Although small in area, RSFs such as these are significant with respect to their landshaping effects. The Slieve League RSF (Figs 7.2 & 7.3) has not only lowered and narrowed the ridge but has produced a shallow cavity with northeast aspect. In future cold stages this cavity could trap snow and nourish a glacierette. Ultimately a small cirque could evolve. The three failures identified near Glencolmcille (Figs 7.4-7.6) have reduced the width of the plateau into which they bite, and two of these have contributed to widening of the glacial trough that is now occupied by the Murlin River.

Given that there have been many cold-temperate (glacial-interglacial) cycles over the course of the Quaternary, it is highly likely that paraglacial RSF has been involved in landshaping on many occasions. The products of earlier episodes of failure may have been subdued or taken from the landscape by succeeding glacial advances and are therefore difficult to recognise. Coarse debris produced by rock avalanching provides glaciers with material for onward transport and incorporation into subglacial and ice-marginal deposits. Thus, RSFs have a significance that is greater than may be first thought.

Other RSFs probably exist in this area of southwest Donegal and a careful scan of Google Earth imagery and/or air photos would doubtless throw up several candidate sites.

References

Ballantyne, C.K., Wilson, P., Schnabel, C. & Xu, S. 2013. Lateglacial rock slope failures in north-west Ireland: age, causes and implications. *Journal of Quaternary Science* 28, 789-802.

Jarman, D. 2006. Large rock slope failures in the Highlands of Scotland: characterisation, causes and spatial distribution. *Engineering Geology* 83, 313-333.

Southall, D.W., Wilson, P., Dunlop, P., Schnabel, C., Rodés, Á., Gulliver, P. & Xu, S. 2017. Age evaluation and causation of rock-slope failures along the western margin of the Antrim Lava Group (ALG), Northern Ireland, based on cosmogenic isotope (^{36}Cl) surface exposure dating. *Geomorphology* 285, 235-246.

Wilson, P. 2004. Relict rock glaciers, slope failure deposits, or polygenetic features? A re-assessment of some Donegal debris landforms. *Irish Geography* 37, 77-87.

Wilson, P. 2017. Periglacial and paraglacial processes, landforms and sediments. In: Coxon, P., McCarron, S. & Mitchell, F. (eds), *Advances in Irish Quaternary Studies*. Atlantis Press, Paris, 217-254.

Wilson, P. & Jarman, D. 2015. Rock slope failure in the Lake District. In: McDougall, D.A. & Evans, D.J.A. (eds), *The Quaternary of the Lake District: Field Guide*. Quaternary Research Association, London, 83-95.